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STUDIES RELEVANT TO IO: A SATELLITE TO THE
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(Laboratory Infrared Studies Relevant to Io,
A Satellite of the Planet Jupiter)

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This report summarizes initial work devoted to identifying spectral features in the thermal spectrum of Io, as obtained by the Voyager infrared spectrometer experiment in March, 1979.

Background and Work Performed

- 1) From ground based observations: identification of Na, K and S in the 'Torus' surrounding Io (Brown, 1974; Trafton, et al., 1974; Trafton, 1975; Kupo, et al., 1976); observation of shortlived transient brightnings (Witteborn, et al., 1976); assignment of a strong absorption feature at 4.1μ to solid SO_2 on Io's surface (Fanale, et al., 1979).
- 2) From Voyager observations: Identification of 9 volcanic plumes (Smith, et al., 1979) and evidence of sulfur flows (Morabito, et al., 1979, Sagan, 1979); association of hot spots (250-600 K) with plume sources and other local regions, identification of gaseous SO_2 and the establishment of very low limits on gases containing C, N and H (Hanel, et al., 1979, Pearl, et al., 1979); direct detection of ionized sulfur, oxygen, sodium and possibly SO_2 in the torus of Io (Broadfoot, et al., 1979; Bridge, et al., 1979; Krimigis, et al., 1979; Vogt, et al., 1979). Together, these suggested a sulfur rich chemistry for Io's surface, with participation of several metallic ions.

To explain the unidentified spectral features in Io's thermal infrared spectrum (Figure 1) we measured the infrared absorption spectra of a number of stable sulfur and oxygen compounds available in our laboratory. The following materials were investigated:

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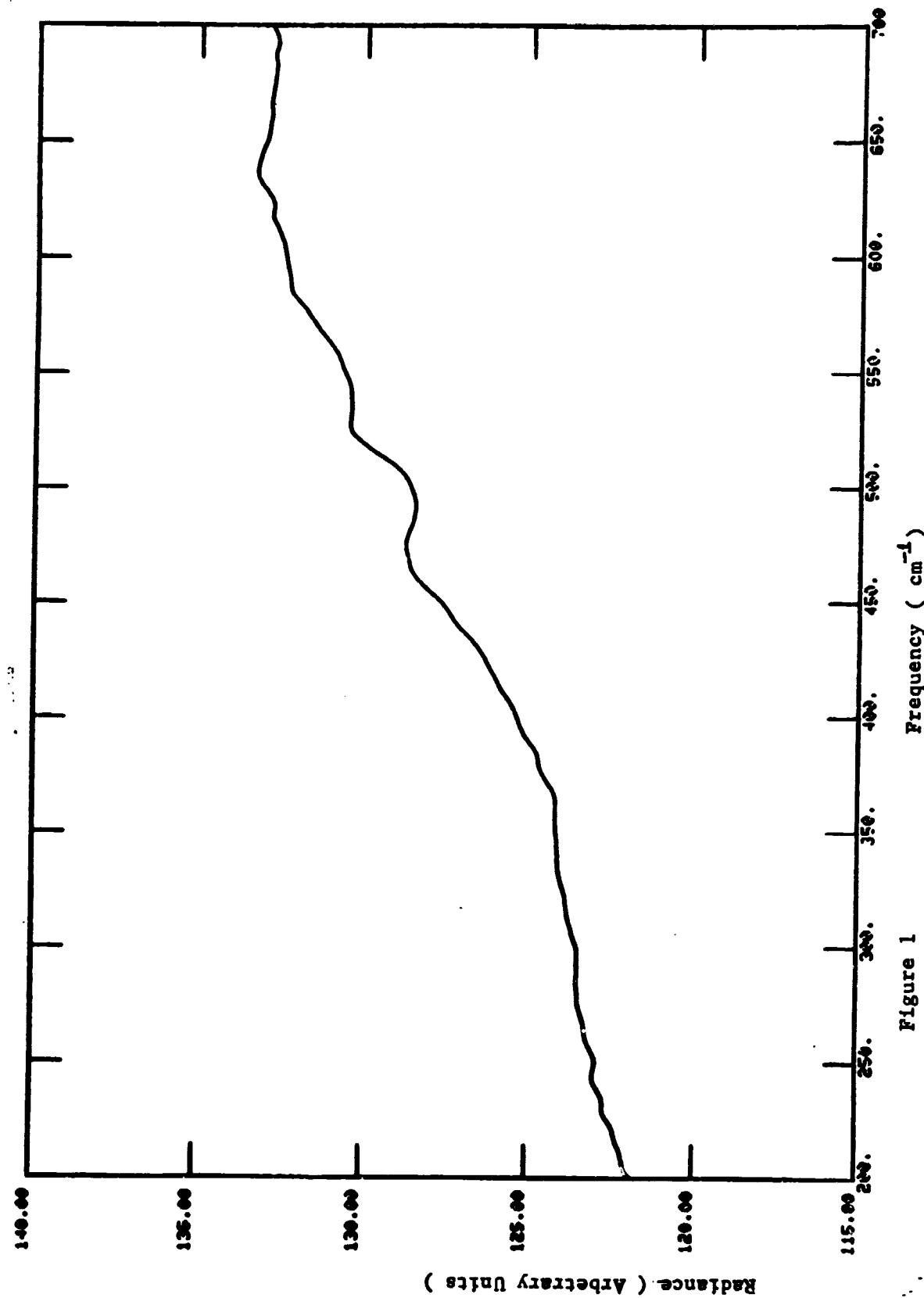


Figure 1

- | | |
|--|--------------------------------------|
| 1. $\text{Na}_2\text{S} \cdot 9\text{H}_2\text{O}$ | 9. K_2SO_4 |
| 2. #1 dehydrated | 10. $\text{K}_2\text{S}_2\text{O}_3$ |
| 3. K_2S | 11. FeS_2 (mineral) |
| 4. Na_2SO_3 | 12. CuFeS_2 (mineral) |
| 5. Na_2SO_4 | 13. MgO |
| 6. NaHSO_4 | 14. CaO |
| 7. KHSO_4 | 15. BaO |
| 8. $\text{Na}_2\text{S}_2\text{O}_3$ | 16. Fe_2O_3 |

Samples were prepared for the measurements in nujol mulls and KBr pellets. The effect of particle size on the band shapes was investigated in a qualitative manner by controlling the grinding time. Initial attempts were also made to record the emission spectra of Na_2SO_4 and Na_2SO_3 coated on a metal plate heated to $\sim 600^\circ\text{C}$. (For this purpose the FTIR facility at Naval Surface Weapon Center, Silver Spring, Maryland was utilized.) Also, the spectra of some mixtures containing two or more compounds from the above list were obtained. All spectra were delivered to Dr. John Pearl, Goddard Space Flight Center, Greenbelt, Maryland.

Although most of the investigated substances have absorption features in the region $200\text{-}700\text{ cm}^{-1}$, none of these provides an exact match with any of the features in the Voyager data. It is noted, however, that the absorption maximum for Na_2SO_4 at $\sim 615\text{ cm}^{-1}$ (Figure 2) corresponds closely with a spectral peak in the Io's spectrum, suggesting that the Io data should be interpreted as an emission rather than an absorption spectrum. The fact that SO_2 has an absorption maximum at $\sim 517\text{ cm}^{-1}$ (Anderson and Campbell, 1977) which

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15

20 μ

25

30

40

50

100

Nuel-Mull Absorption

80

60

40

Specular Reflection -----

20

0

800

600

400

200

cm^{-1}

Figure 2. Infrared Spectrum of Na_2SO_4

also falls very near to a peak in the Io's spectrum, strengthens this assignment. Under this interpretation the broad bands of MgO and CaO may also contribute to the background profile in the Voyager data. Since the particle size affects the band shapes and positions of the characteristic bands, a careful study of such effects may be required to provide a detailed fit of the observed thermal spectrum of Io.

Conclusions

Although not all of the spectral features in the thermal spectrum of Io have been satisfactorily explained, two important results have been obtained.

- 1) Based on a correspondence with absorption bands of Na₂SO₄ and possibly SO₂, the infrared data on Io in the region 700-200 cm⁻¹ appear to represent an emission, rather than an absorption spectrum.
- 2) Although Na₂SO₄ has been tentatively suggested as a surface constituent for Io based on interpretation of the near-IR reflectance spectrum of Io (Nash and Fanale, 1977), the present study appears to provide the first strong evidence for its presence.

Given the strong evidence for an oxidized crustal environment (the presence of sulfur, oxygen and possibly SO₂ in the torus; and the direct observation of gaseous and solid SO₂ on the satellite), and the presence of sodium in the Io torus, the occurrence of sodium sulfate should be expected. A useful extension of the present research would be to study the chemistry of an oxidizing system of

sodium and sulfur, in order to determine the crustal thermodynamic conditions and to determine other likely constituents of the surface material.

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